Weatherwise

Volume 9, Number 4 August 1956

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

An Improved Hurricane Warning Service

The following notes outline the main steps that the U. S. Weather Bureau is taking in 1956 to improve its forecasting and warnings of hurricanes:

A greater number of merchant ships will make regular reports, and more frequent reports will be received when a hurricane threatens.

Improved instrumentation on Air Force and Navy hurricane reconnaissance aircraft will yield better data.

New long-range radar storm detection equipment, similar to that employed at Cape Hatteras in 1955, will be installed at San Juan, Puerto Rico, and Nantucket, Massachusetts, to assist in tracking centers as far as 250 miles away.

Shorter-range radar will be operating at the following hurricane observation points: Corpus Christi, Brownsville, Galveston, Houston, Port Arthur, Lake Charles, Baton Rouge, Burrwood, Shreveport, Tampa, Miami, Charleston, Washington, Boston, New York, Hartford, Worcester, and Swan Island.

New radio communications, camera, and radar-photo equipment have been installed at Cape Hatteras for transmitting radar photos of hurricanes to the forecast center at Washington.

Several additional rawinsonde stations have been established in the Gulf-Caribbean area.

Arrangements have been made to obtain radiosonde upper-air observations from certain ships plying the waters of the Gulf and Atlantic between New York and San Juan

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Cover: A B-50, similar to Project aircraft, flies over the entryway of the National Hurricane Research Project headquarters at the Palm Beach Air Force Base.

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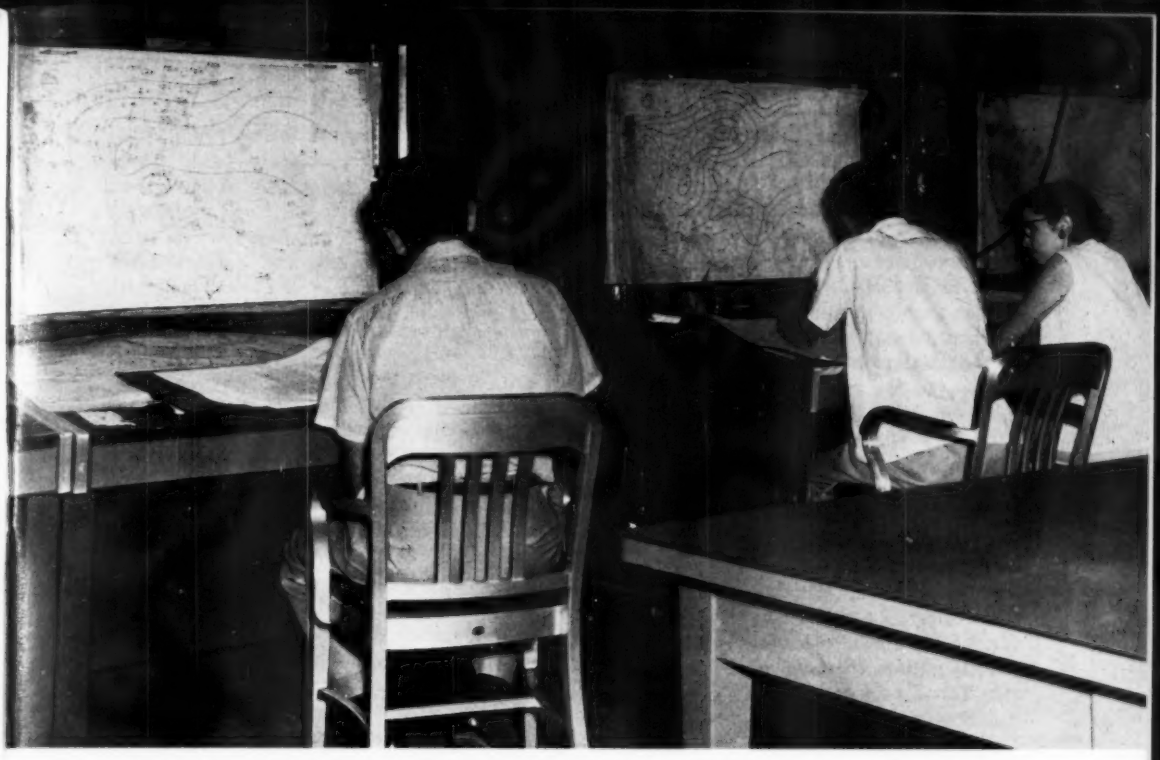


Part of the analysis room of the Research Operations Base showing the sea level, streamlines, and 500 mb analysis sections.

Operation of the National Hurricane Research Project

R. H. Simpson, A. W. Johnson, and R. C. Gentry,
National Hurricane Research Center,
West Palm Beach, Florida

PROGRESS sometimes seems destined to await and to depend upon disaster to spark the support and provide the funding which is required for its accomplishment. Such was the case in 1954 when three disastrous hurricanes, Carol, Edna, and Hazel brought immense destruction to New England and the Atlantic Seaboard, and along with it a renewed public consciousness of the need for more effective measures to protect against hurricanes. As a result, funds not only were appropriated for development of such measures, but in addition, for the first time in history, Congress provided the National Weather Service with a mandate to accelerate its programs of research on severe storms.

As an initial step, the Weather Bureau held a conference of hurricane experts in December 1954 to discuss the hurricane problem and to develop recommendations for research which would enable meteorologists to fashion more effective hurricane warnings. Recommendations from this conference formed the cornerstone of planning for the recently established National Hurricane Research Proj-

ect in which an intensive program of research and development is being launched. The Project will operate a large-scale program of data collection. Specially equipped aircraft will be used to obtain additional details of hurricane structure and information on the more subtle aspects of energy distributions in the storm. In addition, it will draw upon a dense network of newly established rawinsonde stations in the West Indies to study the day-to-day changes in tropical circulations which cause some perturbations to form hurricanes, while others remain innocuous.

In developing plans for the aircraft investigations, the Weather Bureau, through the Department of Commerce, requested the support and participation of the Department of Defense in this phase of the investigations. The Department of Defense, through its Committee on General Sciences, arranged for the Air Weather Service of the USAF to support the Project by providing and operating two TB-50's and one WB-47 aircraft.

Plans for the establishment of new rawinsonde stations in the West Indies required diplomatic arrangements, and negotiations between the U. S. and Mexico, Columbia, the Dominican Republic, Great Britain, France, and the Netherlands for cooperation in establishing and operating the new facilities.

Acting upon the advice of numerous consultants and specialists in all phases of the research operation, plans were gradually completed and during the past six months have been progressively implemented. A Research Operations Base has been established at West Palm Beach, Florida. This will be the nerve center for collection and analysis of new data, and for operation of the three Project aircraft. Other programs including rocket reconnaissance of hurricanes, special investigations of hurricane inception by an oceanographic vessel, special studies of the storm surge, theoretical studies of hurricane models, together with various programs of applied research are already underway. Some of these programs and their plans of operation will be described here.

Primary Objectives

The basic design and objectives of the National Hurricane Research Project have been described recently in the *BULLETIN of the American Meteorological Society* (June 1956) and details will not be repeated here. However, in attacking the primary objective of the Project, namely to develop information with which the best possible warning service and protective measures against hurricanes can be devised, the Project will proceed stepwise as follows:

1. Organize data already available to provide the forecaster with the most useful expressions of synoptic experience possible, developing engineering methods or techniques whenever possible for expressing the anticipated hurricane behavior numerically or in terms of probability of occurrence.
2. Collect additional data from the hurricane vortex and its environment needed to gain a more complete understanding of hurricane circulations and of factors governing its development and movement.
3. Incorporate the result of basic studies from new data into the engineering methods developed at the outset, thereby providing the most effective ultimate tools for hurricane forecasting.
4. Utilize the results of basic researches to investigate the potentialities for modifying or controlling the formation or behavior of hurricanes.

Aircraft Program

The Project aircraft will be used for both routine and special hurricane reconnaissance. During the hurricane season, and possibly throughout the year as the Project develops, flights will be made regularly on approximately a twice-weekly basis. Such more-or-less routine flights will include one of the TB-50's and the WB-47, flying simultaneously. Their purpose will be the systematic investigation of perturbations in the area of hurricane formation and intensification. When possible, reconnaissance will be carried on beyond the hurricane season in order to contribute to the meteorological knowledge of the environmental area, and of the influence of this tropical area on the meteorology of other latitudes. This routine reconnaissance will, of course, be designed to contribute additional observational information from areas in which ordinary land based observations are not normally available.

When there is a possibility of performing reconnaissance in hurricane situations, the routine reconnaissance will be discontinued, and an all-out effort will be made to fly as many research aircraft sorties into the storms as possible. Whenever Project aircraft are all in operating condition at the same time, simultaneous flights of the three aircraft will be made at various levels into the same storm. All three aircraft will be able to make storm passes at several levels, from the lower level of safety to the upper limits of operation for the B-47, something over 40,000 feet.

These flights, simultaneous or otherwise, will be made:

a. first to establish the three-dimensional structure of the storm, assuming circulations are steady and then
b. to investigate the steadiness of these circulations in several storm quadrants, as well as in the eye, and
c. to investigate the source and progress of such circulation surges as may be found.

The reconnaissance described above is designed to contribute to the fundamental understanding of the tropical cyclone and in so doing to open the way for improvement of the hurricane warning service to the public. It will in no way supplant the regular operational hurricane reconnaissance of the Air Weather Service and the Navy, although on some occasions the research aircraft will be used to assist in obtaining operational data.

The wizardry of modern electronics and instrumentation systems has made it possible to instrument the research aircraft more elaborately than has heretofore been accomplished. Basic to the success of the research missions is the installation of automatic navigation equipment, which will permit the frequent and almost instantaneous recording of elements essential to the meteorological analysis, such as latitude, longitude, wind speed, and wind direction. Associated with automatic navigation equipment is a digital recording system, developed by General Precision Laboratories (see fig. 2), which has been designed to record during flight, in punched card form, observations of latitude, longitude, wind direction, wind velocity, pressure altitude, D-value, temperature and time. These elements can be recorded at intervals from one second to one minute, by transmittal of the appropriate sensing impulses to a modified Internatioal Business Machines Type 523 Gang Punch.

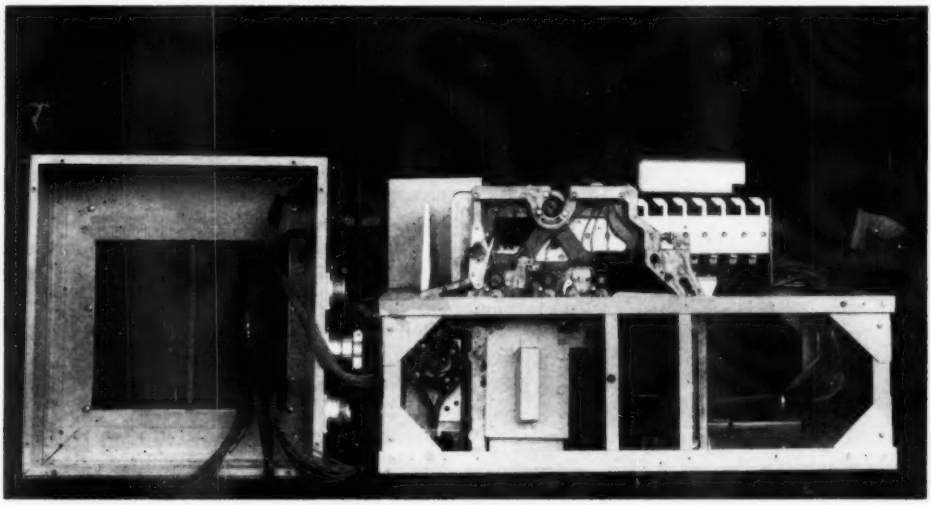


FIG. 2. The modification of a standard International Business Machine's card punch device is nearing the final stage of completion previous to installation in a Project aircraft. General Precision Laboratory, Inc. photo.

Additional recording systems will be carried aloft to serve as a photo panel, which will contain dial indicators of all of the elements contained in the digital system, plus other items such as ground speed, true air speed, radar altitude, drift angle, compass heading, humidity, and additional temperature readings. This photo panel will become the basic data back-up for all elements to be recorded. It can be photographed at the same intervals as those for which cards are punched by the digital system. For certain elements which are best reported by continuous trace instead of instantaneous reading, a Heiland recorder will be used. This instrument will give continuous analogue traces by photographic means of such elements as vertical and horizontal acceleration, liquid water content, humidity, and temperature. It will be synchronized with the central time system on the aircraft.

Of particular interest are some of the additional items of special instrumentation such as the D-value computer. This instrument has been developed under contract with Cook Research Laboratories and will be flown operationally and routinely for the first time on the Project aircraft, enabling very frequent recording of the D-value (difference between radar and pressure altitudes). Humidity will be measured on all three aircraft by means of the infra-red hygrometer built by the Weather Bureau. This instrument, although relatively new in design, has been flown considerably in other experimental aircraft and its dependability has been proven.

The two low level aircraft will each be equipped with a radiometer for measurement of the sea surface temperatures. This instrument was developed by Dr. William Richardson of Woods Hole Oceanographic Institution and has proven useful and reasonably accurate during flights at altitudes up to about 2,000 feet. Through the cooperation of the National Advisory Committee for Aeronautics and the Air Force Air Materiel Command, it will be possible to make measurements of both horizontal and vertical acceleration. In both cases, the equipment is being provided by the agencies mentioned, and they will also perform the data reduction and analysis.

Plans have been made to include specialists in cloud physics on the B-50 crews. These scientists from the University of Chicago will make regular cloud sample observations and will analyze other cloud physics information collected, such as liquid water content. At some time during the course of the Project the aircraft will be equipped for cloud seeding experiments. At present, this phase is only in the planning stage and future experimentation will depend upon studies of the dynamics of the storms. Finally, the aircraft will engage in photography work, both motion picture and still, with emphasis on time lapse work.

Data Analysis Program

An International Business Machines Card Programmed Calculator (CPC) has been installed at the Research Operations Base at West Palm Beach. The primary purpose of this versatile machine is the processing of data collected by the reconnaissance aircraft. Since the data collected will be in binary form, the first operation upon return of the punched cards to the base will be the conversion of the information to the normal decimal form used in computing equipment. Subsequent to this conversion operation, the necessary calibration and correction factors will be applied to the data by machine methods. It will then be possible to process the information in tabular and in grid form. On grid form, the CPC will in effect subtract the movement of the storm by introduction of successive latitude and longitude correction factors, effecting the repositioning of data to its proper location with respect to the center of the storm, regardless of the storm movement during the period of the reconnaissance flight. Separate plot-outs on grid form, repositioning the data, will be made for such elements as D-value, temperature, and wind speed and direction. Thus detailed micro-analyses of these elements may be rapidly made.

This rapid reduction and analysis of reconnaissance data by machine methods is expected to make possible the early re-examination and redesign of flight plans for successive missions, it being assumed that discoveries will be made concerning storm areas or features which should be emphasized in later flights. Figure 3 shows the type of

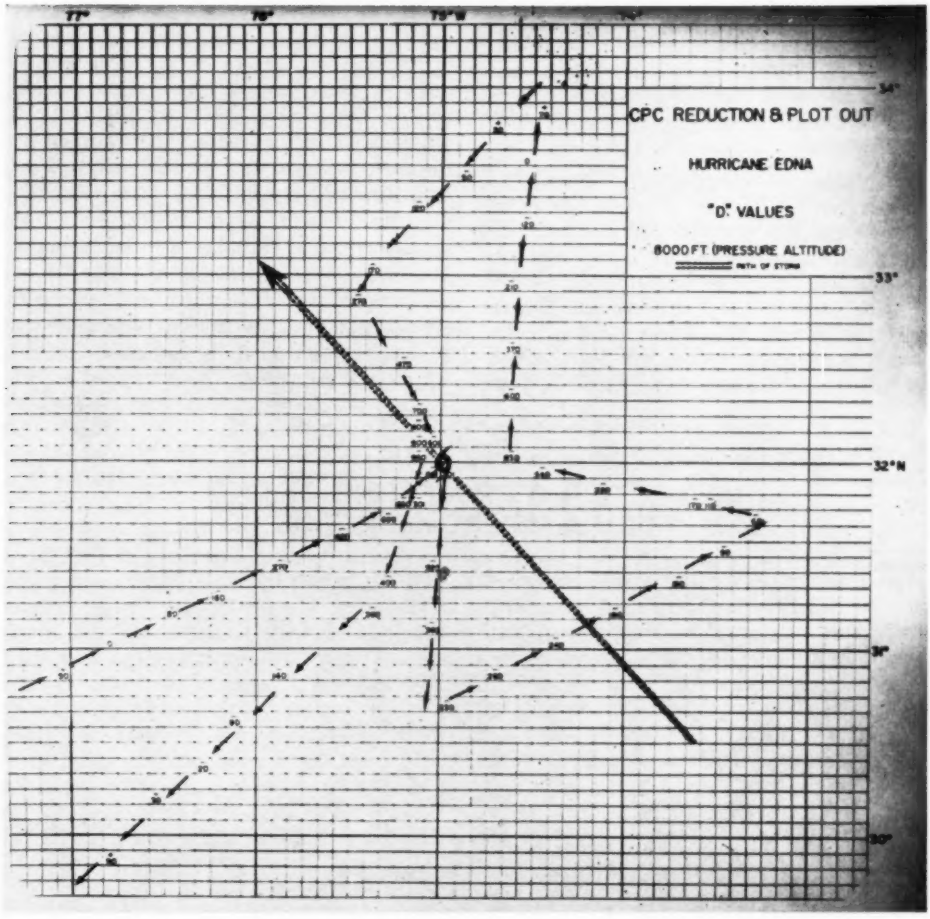


FIG. 3. Schematic representation of repositioned data with respect to the storm center.

grid plot-out which will be used routinely for analysis of reconnaissance data.

At the Research Operations Base an experimental analysis unit has been established with the three purposes in mind:

1. To prepare synoptic weather charts which can be used by the operations officers in planning the flights of the research aircraft.
2. To assemble and analyze data currently for later use in the various research projects.
3. To experiment with various types of tropical weather analysis and to test or to develop various forecast procedures.

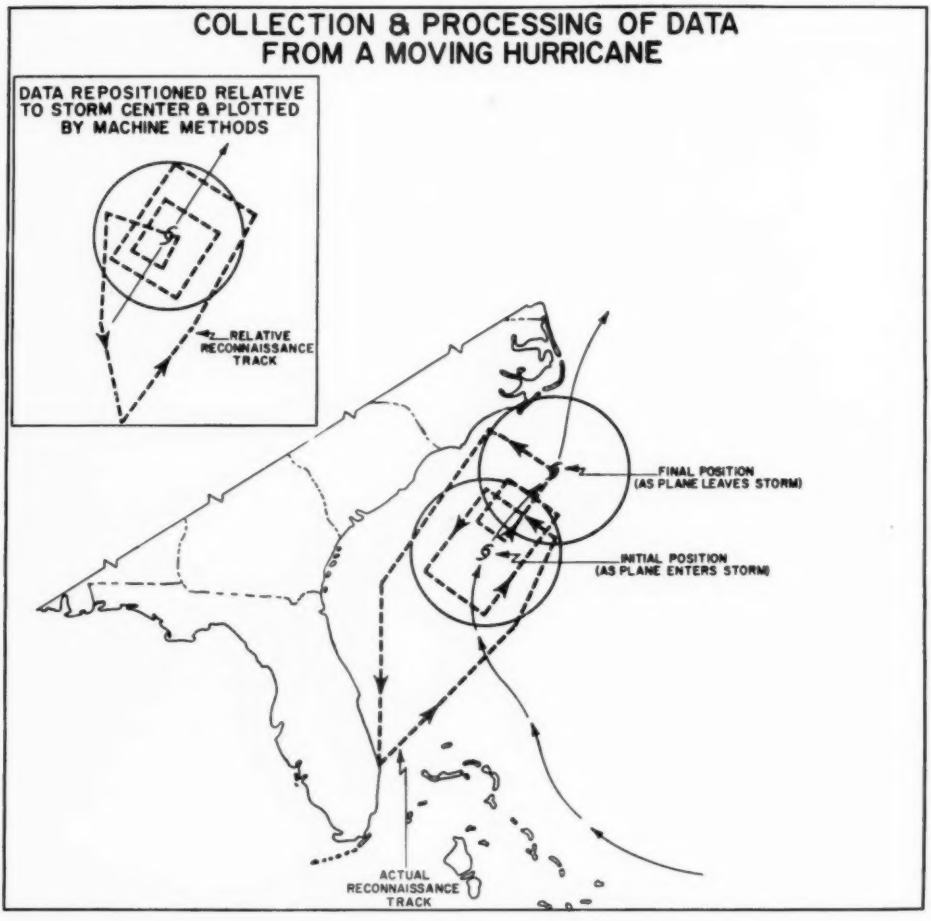
The area for which an intensive analysis of the weather will be made is one extending from 50° W to 100° W longitude and from 10° N to 35° N latitude; that is, from beyond the Leeward Islands west to southwestern United States, and from the northern coast of South America northward to the Carolinas and Bermuda.

The following charts are analyzed once a day on a routine basis in the experimental analysis unit at West Palm Beach:

1. Sea level pressure chart.
2. Low level streamline chart.
3. 700 mb chart.
4. 250 mb chart.

5. Space cross-section extending from Tampa, Florida, to Guadeloupe, French West Indies.
6. Time cross-sections for most of the rawinsonde stations in the West Indies network.

In addition, two combination charts are being analyzed. On one of these charts are plotted the 700 mb and 500 mb data, the thickness values for the layer, and the thermal wind between the two levels. Analyses are made of one of the constant pressure surfaces and of the thickness values. The other combination is the low level isogon-isotach chart which is superimposed on the streamline chart already mentioned. Various experimental charts and experimental types of analyses of the standard charts will be prepared from time to time. As a routine, none of the original charts are analyzed. A reproduction of the original chart is used for the daily analysis, and the originally plotted data are kept available for later reproductions and different types of analyses. This procedure adds flexibility to the Research Program and makes possible not only the re-analyzing of charts for which additional data are available, but also makes possible the use of two or more analysis techniques on the same set of data.


COLLECTION & PROCESSING OF DATA
FROM A MOVING HURRICANE
DATA REPOSITIONED RELATIVE TO STORM CENTER & PLOTTED BY MACHINE METHODS
RELATIVE RECONNAISSANCE TRACK
FINAL POSITION (AS PLANE LEAVES STORM)
INITIAL POSITION (AS PLANE ENTERS STORM)
ACTUAL RECONNAISSANCE TRACK

One of the prime tasks of the Research Operations Base will be to analyze errors in data secured by upper-air soundings. Great difficulty has been experienced in the past by analysts of tropical weather charts because the scale of day-to-day changes in the various parameters is of the same order of magnitude as the instrumental errors of the various observations. In the tropics small-scale perturbations also cause changes in pressure, temperature, and humidity which may be about the same order of magnitude as those caused by the movement of the larger-scale systems. A project is set up at the ROB to analyze deviations of rawinsonde data at individual stations from the indications of the network as a whole. This Project will seek to determine if these deviations are due to instrumental errors or if they are due to "random noise" in the tropical atmosphere.

The card programmed calculator, whose use is described above in connection with the processing of data collected during the hurricane research flights, will also be used for computing vorticity and divergence of the wind field in the analysis area, and for computing momentum transport. Computations of the vorticity and divergence are currently being made for the low level isogon-isotach chart using gradient level winds from pibal or rawin stations and surface wind reports from ships. As the program develops, it is planned that these computations will be extended to some level in the upper troposphere, probably the 250-mb surface. The computations are presently being made using a 2° grid, but the final grid to be used will be selected after experiments have been run to determine what spacing of points gives the most accurate and representative values of the vorticity and divergence. An example of the vorticity computations is given in figure 4 where the vorticity field is superimposed on the streamlines. Another experiment being designed seeks to determine if the analysis of the wind field in areas of sparse data can be improved by advecting the vorticity and divergence fields forward with the speed of the winds and using these "forecasted fields" in areas of little or no data as an indication of trends. It is also planned to experiment with computations of vorticity and divergence based upon the mean flow through a relatively deep layer to determine whether these computations will provide a more conservative mode of synoptic expression.

From the work of various researchers on the general circulation problem, it is evident that much of the energy and momentum of the atmosphere comes from tropical regions.

A portion of the library and seminar room of the Research Operations Base.

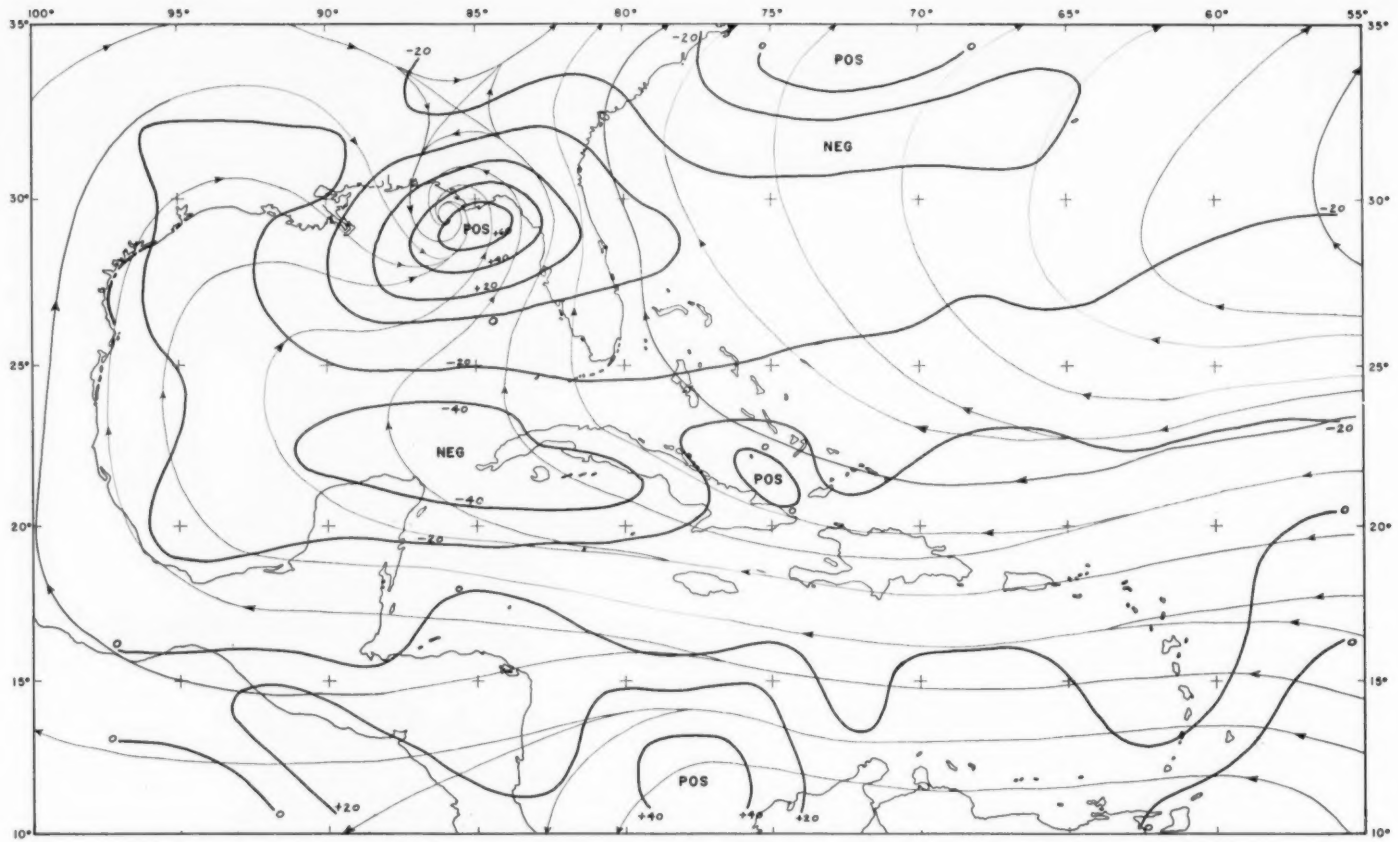


FIG. 4. A sample analyzed chart of the vorticity field computed by machine methods at the ROB. Streamlines at the gradient level are superimposed. These charts will be employed as an analytical tool to determine the displacement of the major vorticity fields. Vorticity values are to be multiplied by 10^{-6}.

As a by-product of the analysis program of the National Hurricane Research Project, it is expected that a new understanding will be achieved of the means by which energy and momentum are transferred from the tropics to the middle latitude westerlies, and possibly of processes leading to acceleration of middle latitude circulations.

Associated Projects

There are several other major components of the NHRP which are being conducted by other research groups from the Department of Commerce, the Department of Defense, and by various other Weather Bureau contractors. More complete reports of these activities listed below will appear in later articles:

1. Rocket reconnaissance of hurricanes is being planned by the Office of Naval Research in cooperation with other units of the Navy and will use the rocket launching facilities of the National Advisory Committee for Aeronautics.

2. Dynamic, hydrodynamic, and numerical prediction models of hurricanes.

3. A "hurricane beacon" (constant volume balloon bearing a radio transmitter) is being developed by the Geophysics Research Directorate of the Air Force in cooperation with the Weather Bureau.

4. Storm surge studies under the leadership of the Office of Meteorological Research of the U. S. Weather Bureau.

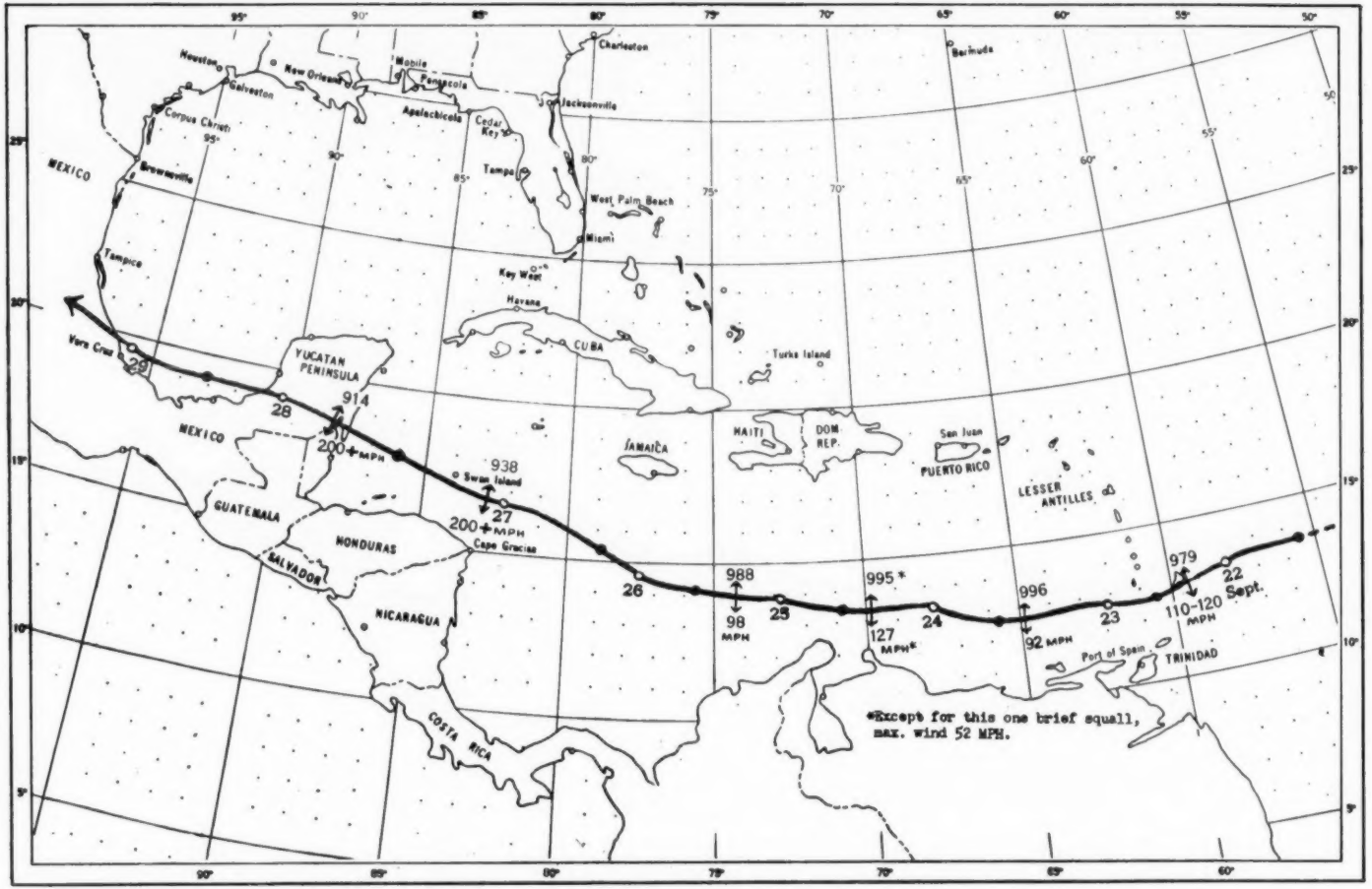
5. Applied research for developing improved engineering techniques to use in hurricane forecasting. These studies are being made at the hurricane forecast centers and at Florida State University.

6. Survey of hurricane warning and protection systems and design of new protective works by the U. S. Engineers and the U. S. Weather Bureau.

7. Investigations of sea surface conditions in areas of hurricane inception. This will be conducted by Woods Hole Oceanographic Institution using their newly-outfitted oceanographic vessel, the Crawford. The vessel will make regular soundings of the atmosphere and of the ocean in the Atlantic east of the Leeward Islands.

The collection of new data by the National Hurricane Research Project is expected to continue for about 30 months, including three hurricane seasons. However, research and development on these data will probably continue at least two or three years before the formal investigations are complete and the results find final applications in forecast procedures.

A chart technician and key punch operator checking data for vorticity computations. General Precision Laboratory, Inc. photo.



Hurricane Janet in the Caribbean Sea, 22–29 September 1955.

Hurricane Janet at Swan Island: A Personal Encounter

From Memory by JOHN LABAN

NOTE: About midday on 27 September 1955 one of the most intense hurricanes of the 20th century passed over Swan Island in the Caribbean, attended by wind of about 200 mph. The only record of meteorological and other events is that described from memory by Mr. John Laban and supplemented by Mr. Francis Lewandowski. The original time sequence as given by Mr. Laban has been modified slightly to conform with the known time the eye passed over the island. (Gordon E. Dunn.)

26 September 1955. Weather all day high thin Cs, wind variable in morning ESE to N, sea condition moderate to rough. Check weather reports were sent to Miami by radio-teletype.

During the afternoon, sea increased slightly. Late evening, around 2000, Moon was full becoming obscured by thickening Cs with cumulus congestus from E, wind increasing to around 20–25 mph. I was at Gliddenville (native village) and told four Grand Caymanian women to prepare on the morrow to go with blankets, food stuff, babies and children, newspapers, to Navy Seismo building where U. S. Navy Seismo operator, Francis Lewandowski, had prepared the building for them. (Late evening, distant lightning and thunder.)

27 September 1955. Time 0155. Just got to bed when there was a wind shift from E to N accompanied by squall with heavy RW—duration about 10 minutes. Awoke, a little late in the morning, prepared Quonset building for storm, cut off butane gas, went to Mess Hall, then station. Weather conditions variable, Fc/Fs – Sc/As. Wind from NE about 20–25 mph. Sea very rough, waves to height of 10–15 feet from ESE or E. In station found all weather personnel up, heard of request for 6-hourly R/s (radiosonde) and hourly surface reports. Time around 0800. Started our R/s instrument. Took sensitivity for R/s run—balloon filled—time around 0830. Wind increasing, sea higher (waves), coconut trees starting to uproot (just a few).

Breazeale and Brown thought we should take R/s earlier before the wind was too strong. Released R/s at 0909. Variable RW, Wind NNE 13.8 mps, station pressure 29.55 inches.

Run very stable. Breazeale atop inflation building operating SCR–658 (rawin apparatus). During run, wind increasing fast. Over intercom, Breazeale said winds to gale force—terrific racket at SCR–658. Hurricane recon plane made 3 or 4 passes. At this time Breazeale terminated run. Winds dangerously high at SCR–658. Run to about 45,000 feet. Run evaluated by Brown and me. Winds by Breazeale and Brown, then transmitted all to Miami. Plane makes last pass to within 100 feet of surface. Pilot says, "You boys have your hole ready?" We answer with yes. He comes back with "Better get into it—this one (hurricane) is a bad one." Says there is a squall line 50 miles E of station. During this time sea and wind increased, coconut trees beginning to uproot, coconuts flying, waves to 70 feet on south side from ESE. Wind over average of 50 mph. Charles A. Dowd, Jr. (Elect. Tech.-CAA), sends message to his wife and mine that we are OK, etc. Time is around 1100. Then Dowd sends message saying antennas going down—abandoning station. Squall almost upon us. Dowd and I cover radio transmitters and receivers with empty U. S. mail bags. We went back into weather room—north corner of building ripping.

Weather RW. Wind over 75 mph from N. Sea ESE, waves to 70 feet. Dowd goes out to west corner of station to see if any flying debris. I go back into building to get three flashlights, put forms in drawers, read wind—over 100 mph average from N. Pressure 29.065. Time a little after 1100. We both dash for Mess Hall where cook Henry Alsted Glidden had lunch ready. We all pitched in to re-inforce shutters on north side, then had lunch, except Lewandowski who stayed in

Seismo building. Hurried with lunch—shutters ready to fly in. Cleared most of dining table off. We went into kitchen, looked out of kitchen door (south side), saw debris flying—asbestos from station—SCR–658 turns over atop inflation building. Shutters in dining room flying in, we see that kitchen shutters ready to go also. Wind increased now to (est.) over 120 mph about 1130. We all move into pantry and wait for about five minutes, when kitchen shutters blow in. I kept pantry door open to equalize pressure. Things are crashing in dining room and kitchen, we go to bathroom, then into Sims' office in last room of building on south side. Racket of crashing things in other parts. Someone suggests we go to Seismo building but it seemed too dangerous. Moved office desk in front of office door to kitchen, time estimated to be about noon. There are seven of us here, Sims, Breazeale, Guarcello, Brown, Dowd, Al Glidden (cook) and I. There is a silence among all, Glidden with fear reflected in his eyes—others with thoughts and prayers to themselves. As for myself, I had dreamed two days previously that the storm would hit us and that I had read the message sent to Miami that I was dead—the only fatality. I was asking myself when was I going to get it. I prayed for all of us and those people, men, women, and children, down at Gliddenville. I presumed all were dead or injured, they being closer to the sea by about 300 feet. I asked Brown again what the time was—1215. The wind was estimated at over 150 mph now and the rain was going by between the buildings in a horizontal watery stream. I could discern the living quarters about 25 to 30 feet away. About two inches of water was on the floor. Time estimated at about 1230. A loud CRASH and we all made a dive for the space under the office desk, 30″ × 24″. How all our heads got into that space is a wonder. Second later we looked up and saw we were without a roof. Some walls were standing and we went over the side of the building platform (made of concrete pillars) and put our heads along the edge of the platform. We were all given a baptism of 500 gallons of diesel fuel. We were completely soaked, our eyes smarting, our mouths, ears, and heads covered with diesel fuel. Someone suggested we get under the building and take a chance from flying debris. Then another suggestion—to make 125 foot dash to U. S. Navy Seismo concrete building where Lewandowski was. Sims and Guarcello went first and are knocked off their feet. Then the rest of us made the dash. Lewandowski (Ski) is most surprised to see us, especially in our condition of fright and wild stare (diesel fuel in our eyes).

We immediately tried to wipe the diesel fuel from our eyes but there were no dry cloths around. A few moments were spent in talking, cussing the fuel in our eyes, scratches and abrasions on our feet, etc. Someone said that the people from Gliddenville are coming up and there was a sort of let up in the wind and rain (R −). The eye of the hurricane is approaching. We dashed out to the desperate people—men carrying children and babies in thin blankets and bags—men and women with fright in their eyes. Some of the men had cuts and scratches, but no one was seriously hurt. Thank God, all are accounted for. All we could see was havoc and damage. All that was standing of the Mess Hall that we had been in was the proverbial toilet—atop the concrete platform.

We are all in the Navy Seismo building. We are pretty crowded—have to set up chairs etc. for some to sit on—there is water on the floor. Elapsed time spent at this time is about 30 minutes during which the eye of the hurricane passes. During "Eye" I was unable to see sky due to blindness from diesel fuel. Wind resumes its howl after we are hit by SE and S winds—pressure inside Seismo building is painful to ears—rain resumes—the building vibrates—length of time (est.) from 1430 to after 1800 winds still hurricane force.

After 1800 the Caymanian boys go down to what is left of Gliddenville to see what food can be salvaged. A 2-burner oil stove is found and food that is usable—a meal is made and food is handed out to all who are hungry. After the meal, preparation for spending the night in the Seismo building. Agricultural buildings reported in good shape —the "Ranch" has water, gas, and a home butane stove. Al Glidden and I clean out the ranch for the future cooking and feeding of all on the island. The sky is scattered but the wind is still gale force. The island seems desolate—out of 10,000 coconut trees, a few

are still standing. Most have been snapped at an average height of 15 feet from the ground. The Caymanian and Honduranian men bed down in the Agricultural barns, others in the Seismo building.

28 September. Preparations of assembling order and sanitation, surveying damage, finding edible food, water and clothing. People are preparing for a comfortable stay. Breazeale and I chlorinate 55,000 gallons of water. Roland Jackson, one of Capt. Donald Glidden's men, 60 some years of age, makes a venture around the island to locate cattle and survey conditions in the former woods and coconut groves. Report of isolated cattle, some beaches on SE side washed clean of all sand—other beaches piled with more sand—the woods and coconut groves almost impenetratable because of fallen trees and shrubs. On the west side of island, estimate that one acre of bluff and soil washed away by pounding high waves. Weather today is windy, high scattered and sunny. Preparations are going on to throw off debris from power shed to get to work on at least one generator. All able men are put to work—others help in setting up a systematic food preparation and sanitation. A day is spent in throwing off debris from generators. Late that afternoon Air Force C-54 flys low—later a seaplane and other rescue craft are overhead. Water and rations are dropped. 34th Rescue Sqd. from Coco-Solo, Canal Zone, drops Walki-Talki, communications set up with aircraft overhead (MATS). In days that follow more air-drops of food. Charles Dowd of CAA has one of the station receivers working—with MATS relaying, we listen on receiver—we have a listening schedule to Miami and MATS.

29 September. Banana boats arrive from Costa Rica to check on us. Brown departs for Tampa. Hamilton Bros. of Tampa sends us free food and any assistance we may need from his ships.

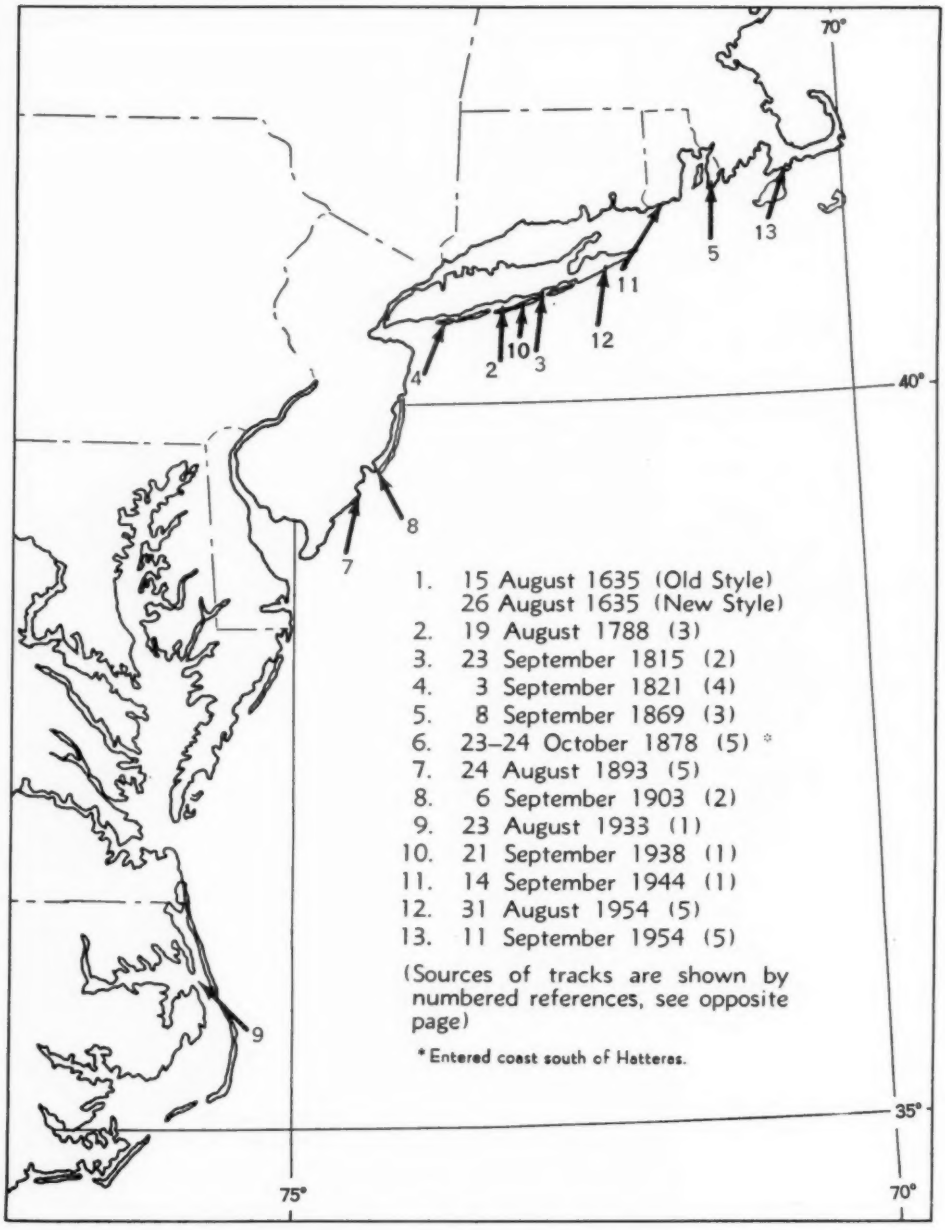
30 September. U. S. Navy arrives to evacuate and survey.

1 October. Guarcello and I depart for Grand Cayman and Miami.

NOTE BY GORDON E. DUNN

Half-blinded by the fuel oil, Mr. Laban could not describe very completely conditions in the eye of the storm. Remarks by Aerology Mate 3rd Class Francis D. Lewandowski, U. S. Navy seismograph tender, follow: Eye lasted from 1310 to 1335 approximately. Station near north edge of eye. Always some wind 15 to 35 knots. Stratus type clouds, but sun occasionally visible. Vertical wall cloud occasionally visible through breaks. Distant roar audible at all times. About 10 minutes for wind to subside from about 200 mph to 20–40 mph. Increase of wind after eye passed more rapid than diminution before. Few birds in eye. Sky had hazy milky appearance. No sense of oppression during eye. Wind NNE before eye, S after eye. No particular lurid sunset evening before storm. Ice box in mess hall exploded during hurricane. No tidal wave. Many fish observed washed up on land and 4 out of 5 had eyes popped out.

The wreck of the Raob inflation shelter after the passage of Janet. Photo by CAA (Jenkins).



A chart of the known tracks of hurricanes which have entered the United States north of Cape Hatteras. Arrows indicate the point of entry and the direction of movement.

Hurricanes Entering U. S. Mainland—Eastport to Hatteras 1635-1955

CONRAD P. MOOK, *U. S. Weather Bureau Forecast Center, Washington National Airport, Washington, D. C.*

THE June 1955 issue of *Weatherwise* contains a chart prepared by the writer showing the points at which the centers of hurricanes entered the U. S. mainland between Brownsville, Texas, and Cape Hatteras, North Carolina, for the period 1896 through 1954. The attached chart presents similar data on U. S. storms passing inland north of Cape Hatteras. Those selected for inclusion during the period 1900–1949 are those included in Hydrometeorological Report No. 32 (1) * with the addition of one storm, that of 16 September 1903, which is included in the list of severe tropical storms in New England published by Dr. I. R. Tannehill in his book *"Hurricanes"* (2). Insofar as possible, an attempt has been made to locate the point of entry of the earlier storms listed by Tannehill dating back to 1635. The opposite chronological listing of hurricanes for the period 1635–1955 incorporates those storms listed by Tannehill for the period 1635–1903 as having affected New England. Thus, prior to 1900 a storm similar to that shown in the chart for 6 September 1933 would not be included. Information is lacking regarding the track of the 1635 storm, but it is included in the list below in the hope that it can be later filled in by readers of *Weatherwise*. It is interesting to speculate that this may be the same storm listed by Poey and quoted by Tannehill as having caused considerable damage in the Windward Islands in August 1635. One intense hurricane of small size, not mentioned in Tannehill's New England list, should be noted. It traversed the Providence-Boston area with a narrow path of major destruction on 9 October 1804. The arrows on the chart show the direction of travel on each storm as it crossed the coast.

* See "Fifty Years of Hurricanes" by Vance A. Meyers and Lillian K. Rubin in the August 1953 issue of *Weatherwise*.

REFERENCES

(1) U. S. Weather Bureau, *Hydrometeorological Report No. 32*, 1954.

(2) I. R. Tannehill, *Hurricanes*, Princeton University Press, 9th edition, 1956.

(3) F. G. Tingley, Mss. notes in Marine Climatology Section, U. S. Weather Bureau, Washington, D. C.

(4) W. C. Redfield, "Remarks on the Prevailing Storms of the Atlantic Coast of the North American States," *American Journal of Science and Arts*, Vol. 20, 1831, New Haven, pp. 1–36.

(5) U. S. Weather Bureau, *Monthly Weather Review*, 1872–1955.

The Hurricane Girls Of '56

Anna — Betsy — Carla — Dora — Ethel — Flossy — Greta — Hattie — Inez — Judith — Kitty — Laura — Molly — Nona — Odette — Paula — Quenby — Rhoda — Sadie — Terese — Ursel — Vesta — Winny — Xina — Yola — Zenda.

The Three Most Severe Hurricanes of Record

City	Date	Maximum Wind	Lowest Barometer	Date	Maximum Wind	Lowest Barometer	Date	Maximum Wind	Lowest Barometer
San Juan, P. R.	9/13/28	149	28.83	9/26/32	120	28.95	9/10/31	90	29.17
Havana, Cuba	10/10/1846		27.05	10/20/26		28.07	10/18/44		28.50
Nassau, B. W. I.	9/26/29	140(a)	27.64	9/16/28	120(a)	28.08	7/25/26	120(a)	28.90
Brownsville, Tex.	10/8/67			1886	—		1887		
Corpus Christi, Tex.	8/26/45	100	29.48	8/18/16	100	29.07	9/14/19	100	28.65
San Antonio, Tex.	8/30/42	74	29.04	8/20/86	80	28.67	8/19/16	68	29.63
Port Arthur, Tex.	8/7/40	91	28.87	9/23/41	73	29.37	10/4/49	70	29.57
Galveston, Tex.	9/8/00	87(a)	28.55	8/15/15	91	28.63	7/27/43	63	28.95
Houston, Tex.	8/17/15	80SE	28.20	9/23/41	75E(a)	28.66	7/27/43	84NE	28.95
New Orleans, La.	9/29/15	98	28.11	9/19/47	110(a)	28.57	9/20/09		
Baton Rouge, La.	9/19/47	96	28.69						
Mobile, Ala.	9/27/06	75(a)	28.84	7/5/16	98	28.92	10/18/16	87	29.22
Pensacola, Fla.	9/27/06	64E	29.17	7/5/16	79	29.31	9/20/26	88	28.56
Birmingham, Ala.	7/–/16	38		8/31/50	45	29.39			
Montgomery, Ala.	9/29/17	34	29.42	9/20–21/26	38	29.71	7/31/36	33	29.78
Tallahassee, Fla.	6/30/86	80(a)		10/5/77(h)			8/23/51(h)		
Macon, Ga.	8/10/28	39	29.49						
Tampa, Fla.	9/3–5/35	75(i)	29.31	10/18–19/44	56(i)	28.55	10/25/21	53(i)	28.31
Ft. Myers, Fla.	9/17/47	90(a)	28.67	10/19/44	65(a)	29.02	9/18/26	80(a)	29.47
Key West, Fla.	9/9–10/19	91	28.83	10/17/10	84	28.47	10/11/09	72	28.52(1)
Miami, Fla.	9/18/26	123(i)	27.61	9/15/45	86	29.16	10/17–18/50	97	28.20
West Palm Beach, Fla.	9/16/28		27.43	9/17/47	100	29.02	8/26/49	120	28.17
Lakeland, Fla.	10/–/44	57	28.68	9/–/45	34	29.33	8/–/49	61	28.64
Orlando, Fla.	10/19/44	82	28.94	9/16/45	66	29.29	10/8/46	64	29.31
Daytona Beach, Fla.	10/19/44	59	29.06	10/18/50	53	29.33	8/27/49	50	29.65
Jacksonville, Fla.	10/18/50	72	29.43	10/19/44	65	28.94	9/29/96	76	28.90
Savannah, Ga.	8/27–28/93	72	28.29	8/11/40	90N	28.81	10/15/47	85NE	28.77
Charleston, S. C.	8/27–28/93	120	29.08	8/27/11	106(a)	29.30	8/25/85	80–100	28.73
Greenville, S. C.	9/30–1/29			8/11/40	49		10/19/44		
Asheville, N. C.	7/9/16		29.77	8/11/28		29.63	8/14/40		29.70
Charlotte, N. C.	8/27–28/93	34	29.13	7/14/16	57	29.75	9/18/28	23	29.58

City	Date	Maximum Wind	Lowest Barometer	Date	Maximum Wind	Lowest Barometer	Date	Maximum Wind	Lowest Barometer
Raleigh, N. C.	10/15/54	73	28.75	9/13/93	36(i)	28.67	8/28/49	46	29.63
Wilmington, N. C.	10/15/54	98(j)	28.68	9/19/55	92(j)	29.14	8/11/55	83(j)	29.10
Cape Hatteras, N. C.	10/15/54	56	29.25	9/14/44	110	27.97	9/12/33	76	28.26
Cape Henry, Va.	8/23/33	82	28.67	9/18/36	84	29.16	9/14/44	134	28.86
Norfolk, Va.	8/18/79	72(i)	29.12	8/23/33	57(i)	28.68	10/15/54	78	28.99
Richmond, Va.	10/15/54	68	28.75	8/23/33	44NE	29.75	9/1/52	50SE	29.75
Lynchburg, Va.	10/18/16	80		10/15/54	59	29.01	9/17/45	44	29.99
Washington, D. C.	10/15/54	98	28.80	9/29/96	70(a)	29.14	8/12/55	58	29.11
Baltimore, Md.	10/15/54	73	28.93	8/23/33	57	29.08	8/12/55	54	29.04
Atlantic City, N. J.	9/14/44	91	28.73	9/21/38	72	28.99	10/15/54	66	29.29
Philadelphia, Pa.	10/15/54	73	29.19	8/13/55	67	29.41	9/14/44	34	29.33
Wilmington, Del.	10/15/54	58	29.08	8/13/55	40	29.34	9/1/52	30	29.67
Reading, Pa.	10/15/54	72	29.07	8/12–13/55		29.40			
Harrisburg, Pa.	8/13/55	37	29.29	8/18/55	20	29.67	10/15/54	50	28.93
Trenton, N. J.	10/15/54	57	29.27	9/14/44	54	29.19	9/21/38	38	29.07
Newark, N. J.	9/14/44	66	29.17	9/21/38			10/15/54	48	29.38
New York, N. Y.	9/21/38	80	28.72	9/14/44	99	29.08	10/15/54	113	29.39
Bridgeport, Conn.	9/21/38	100(a)	28.17	8/31/54	60(j)	28.87	9/11/54	56(j)	29.11
New Haven, Conn.	9/21/38	46	28.11	9/16/03	62	29.71	11/13/04	50(i)	28.65
Hartford, Conn.	9/21/38	59	28.04	9/14/44	62	28.94	8/31/54	56	28.87
Block Island, R. I.	9/21/38	82(k)	28.66	9/14/44	82	28.34	8/31/54	100	28.50
Albany, N. Y.	9/21/38	42	28.68	10/15/54	42	29.40	9/29–30/96	36	29.61
Burlington, Vt.	10/15–16/54	70	29.39	9/21/38	56	28.68			
Providence, R. I.	9/21/38	95	28.90	8/31/54	90	28.89	9/23/15		
Nantucket, Mass.	9/14/44	79SW(d)	29.04	8/31/54	72(e)	29.32	9/11/54	73SE(e)	28.18
Boston, Mass.	9/21/38	87	29.09	8/31/54	100	28.83	9/11/54	87	28.75

(a) Estimated (e) Fastest mile (j) Gusts
(d) Extreme velocity (i) 5-minute velocity (k) Anemometer blew away

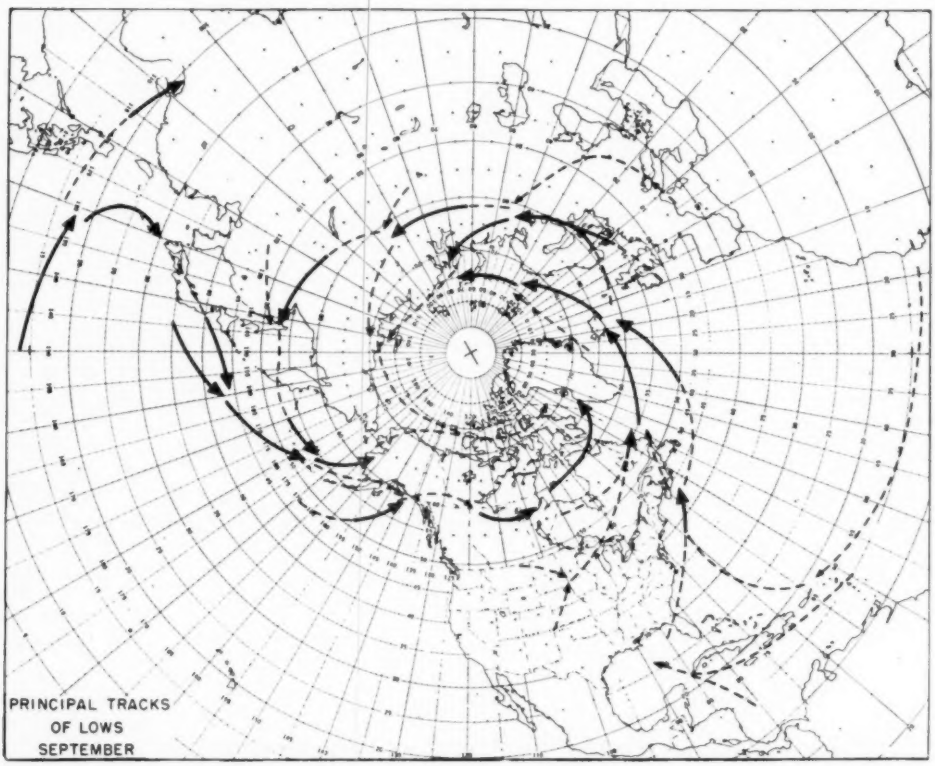
The above record of severe hurricanes was compiled by Mr. Gordon Dunn and his associates at the U. S. Weather Bureau, Miami. The data are mainly for the period since 1871, but some stations have much shorter records.

This is the second of a series of six articles which will appear in forthcoming issues of *Weatherwise*. Each article will discuss the prevailing tracks of highs and lows for the two months following the publication month.

Prevailing Tracks of Lows and Highs

WILLIAM H. KLEIN,
Extended Forecast Section,
U. S. Weather Bureau,
Washington, D. C.

Principal tracks of cyclones and anticyclones at sea level. The prevailing direction of motion of systems is indicated by the arrows. Heavy solid lines denote primary tracks—those which are most frequent and generally indicated by various data sources; thin dashed lines denote secondary, less frequent, and less well defined tracks. All arrow heads end in areas where cyclone frequency is a local maximum. Here the tracks may cross, branch, and merge, although not specifically so drawn. Locally preferred regions of genesis are indicated where secondary or primary tracks begin, whether in centers of maximum cyclone frequency or elsewhere. An area of frequent genesis is also indicated when a single secondary track changes to a single primary track or when two secondary tracks merge to form a primary track, with a break between dashed and solid lines.



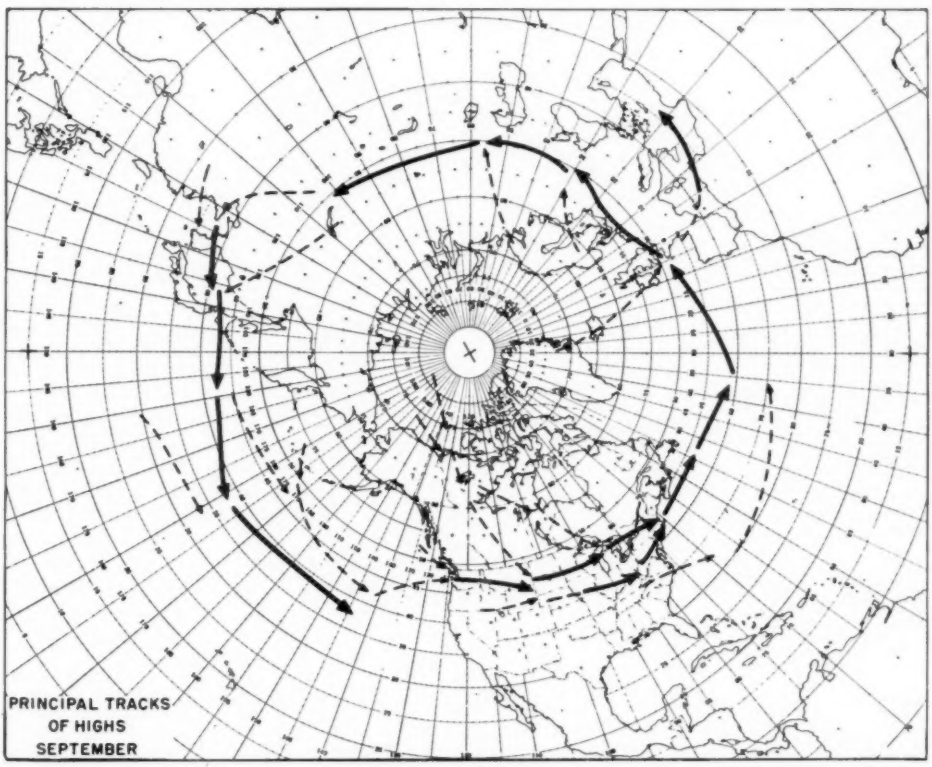
September—Cyclones

ALTHOUGH September is generally considered to be the first month of autumn, it greatly resembles August in many aspect of its cyclonic activity. The prevailing westerlies and associated storm tracks are still far to the north. In North America cyclones continue to be far more frequent in Canada than in the United States, and the primary storm track remains around 60° N. The Icelandic area again leads the hemisphere in number of lows per 5 degree quadrangle. Primary storm tracks are still located north of the Aleutians and in southern Scandinavia, with secondary tracks between 70° and 75° N. in the American and Siberian Arctic. The prevailing tracks of tropical storms are generally similar to those of August, although some eastward displacement is evident in the Atlantic, and cyclogenesis in the western Caribbean is resumed. In most parts of the hemisphere affected by tropical cyclones, their monthly frequency reaches its annual maximum in September.

There are several characteristics of September which are typical of the cooler portion of the year. Most prominent is the marked increase in cyclone frequency over open water west of Norway and north of Europe, where primary storm tracks are located every month from September through April. At the same time cyclonic activity returns to the Mediterranean region, where storm tracks are absent only during the summer period from June to August. Other typically summer features which disappear during September are: the center of maximum cyclone frequency (and associated storm tracks) in the interior of Alaska, the center of minimum cyclone frequency in the Sea of Okhotsk, and the secondary storm track between 80° and 85° N. in the Arctic.

September—Anticyclones

The principal anticyclone tracks during September resemble those of the summer months for the most part. A well-defined primary track still extends in a zonal direc-

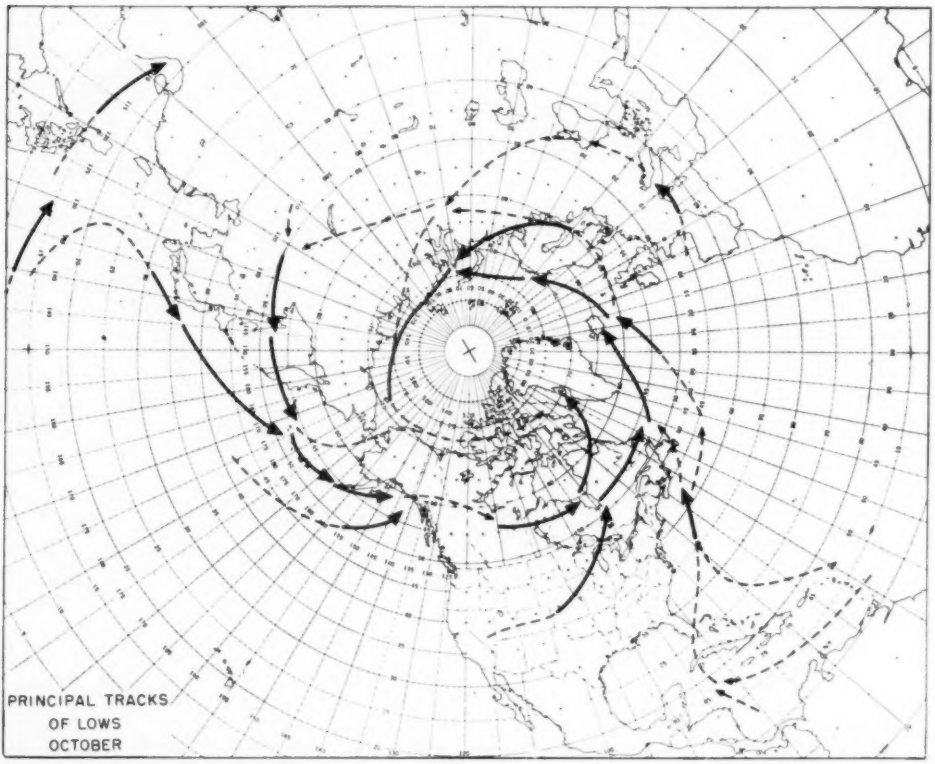


tion across the United States and the Atlantic around 45° N. and across Europe about 50° N. The northern Plains region of the United States again leads the hemisphere in number of migratory highs and frequency of anticyclogenesis, while the eastern Pacific continues to lead in number of days with high centers. The primary anticyclone tracks suffer some southward displacement in Siberia and the Pacific, but they retain their zonal orientation and well-defined nature. The tracks of polar highs are only of secondary importance, not only in North America as in August, but also in all other parts of the Northern Hemisphere.

Some harbingers of autumn appear during September. Most significant, perhaps, is the renewal of anticyclogenesis in the Great Basin. From here a secondary anticyclone track extends across the central U. S. into a pronounced center of maximum anticyclone frequency located over West Virginia. In the Atlantic the secondary anticyclone track between 30° and 35° N. is once again directed from west to east, as the zone of subtropical easterlies normally shifts southward. Anticyclone frequency increases in eastern Asia and the western Pacific, and three centers of high pressure appear in Siberia on the normal sea level map. On the other hand, a sharp fall in anticyclone frequency occurs over previously cold water surfaces, such as the Sea of Okhotsk and Barents Sea, where primary anticyclone tracks of August vanish in September. The marked resurgence of cyclonic activity in these two seas during September has previously been noted.

October—Cyclones

October is a typical fall month in which cooling due to decreasing insolation occurs more rapidly over land than adjacent water in many areas. As a result, new centers of maximum cyclone frequency now appear over James Bay, the Black Sea, and the Sea of Okhotsk. At the same time cyclone frequency increases in previously existing centers over the Gulf of Alaska, Davis Strait,



Adriatic Sea, and Kara Sea. In the last named sea, cyclone frequency reaches its annual maximum during October. Also noteworthy is the increased frequency of cyclogenesis over the Gulf of Genoa and vicinity, which is one of the most cyclogenetic areas in the hemisphere every month from October through March.

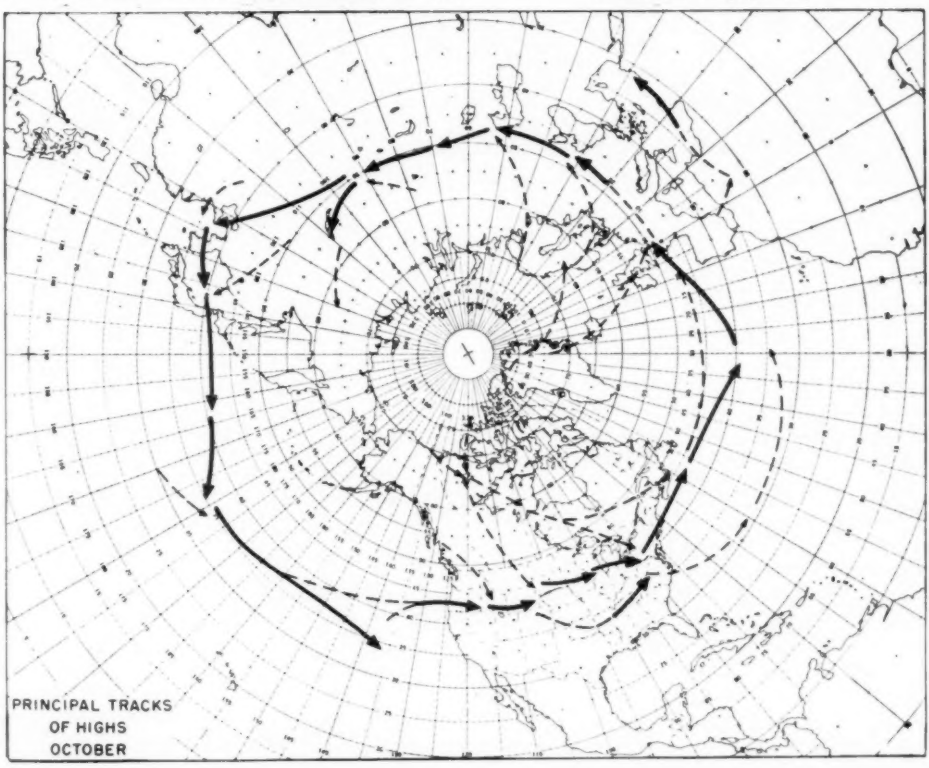
During October the main belt of westerlies normally begins to move south. A corresponding southward displacement of the principal storm tracks is evident in Canada, the Pacific, and eastern Siberia. Increased speed of the westerlies and strengthened meridional temperature gradient at middle latitudes are accompanied by greater frequency of cyclonic activity in the United States, southern Canada, western Mediterranean, southern Japan, and the Alaskan peninsula. In all of these areas secondary storm tracks of September are converted to primary tracks during October.

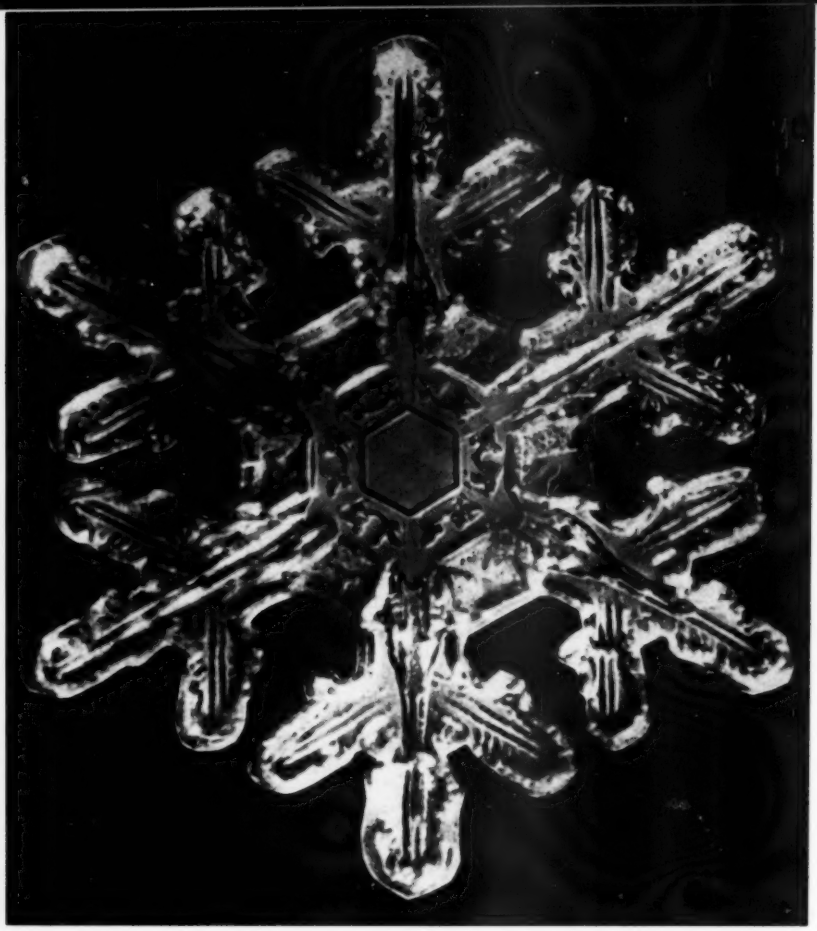
The tracks of tropical storms are also farther south in October, particularly in the Caribbean and Pacific. Southward shift of the westerlies results in earlier and more frequent recurvature, so that the main tracks of tropical storms are now definitely east and south of Japan and Florida. The frequency of tropical storms increases somewhat in the western Caribbean, decreases markedly in the Atlantic and Gulf of Mexico, and decreases slightly in other areas.

October—Anticyclones

One of the oustanding features of October is the prevalence of anticyclonic activity in the central Appalachian mountain region of the United States, where a prominent center of high pressure is located on the normal sea level map. Near West Virginia there are more days with high centers and more different highs than in any other 5° quadrangle in the Northern Hemisphere. In this area anticyclone frequency is greater during October than any other month of the year, with a resulting high incidence of smog and "Indian summer" weather.

(*Continued on page 135*)





The Preparation of Snow Crystal Replicas—VI

VINCENT J. SCHAEFER, *Director of Research,*
The Munitalp Foundation, Inc.

SNOW crystals, which seem to defy all natural laws of melting and evaporation, will be the subject of our discussion this time. Under the microscope these crystals appear to have all the properties of the natural crystals that fall from the sky in such abundance and almost limitless variety. The "crystals" of our discussion are plastic replicas made by coating the actual crystals with a thin plastic membrane, which hardens and traps the crystal within a tough, horny, transparent skin, literally fossilizing the crystal and thus producing a permanent and exact copy of its outside surfaces.

The replica technique is an extremely useful method for preparing a permanent record of snow crystals, whether they occur in a laboratory cold chamber, our backyard, on a distant mountain, in the polar regions, or high in the sky where they might be gathered with an airplane. The technique is extremely simple and, with proper procedures, nearly foolproof.

The method is based on the use of a synthetic resin, called polyvinyl formal,* dissolved in the solvent, ethylene dichloride.

This solvent has the property of evaporating readily at cold temperatures, but more

* Trade name: Formvar 15–95, Shawinigan Products Corp., Springfield, Mass.

important—of causing no damage to the structure of even the most delicate snow crystals. It also has the very useful property of not only wetting the surface of snow crystals, but it will actually creep up over their surfaces when they are bulky and project above the layer of solution used to preserve them. In this manner the final replicas possess a 3-dimensional structure. This feature is very important because some crystals such as the type called capped columns have a shape which would be difficult to preserve, if this phenomenon did not occur.

The replica solution should have a concentration of 0.5 to 3 per cent by weight, depending on the bulk and size of the crystals to be preserved. The tiny twinkling diamond dust crystals, which are of microscopic size, are best preserved in the more dilute solutions. Large particles like graupel, snow flakes, and large stellar crystals require the 2 or 3 per cent solutions.

There are many methods that may be used for preparing snow and ice crystal replicas. Since in this series we are primarily concerned with simple cold chamber experiments, we will describe the method to be followed for making replicas of microscopic crystals formed under controlled conditions. The crystals formed in a cold chamber ordinarily range in size from 25 to 250 microns (0.001″ to 0.010″ in major cross section) and thus are similar to naturally formed "Diamond Dust," the type of crystals which often form at low levels on very cold days in the middle and polar latitudes and also comprise ice fog. Thus it becomes quite easy to prepare snow crystal replicas in any climate or region of the world, even in places where natural snow crystals never form under natural conditions. Fortunately, this technique is also the simplest and most effective procedure for preparing storm sample replicas in regions where natural snow occurs.

If an open top cold chamber is used for preparing snow crystals (such as described in Part 1 of this series—*Weatherwise,* April 1955), the replica solution is held in a container near the top of the chamber in such a position that it never gets colder than − 5° C. (23° F.).

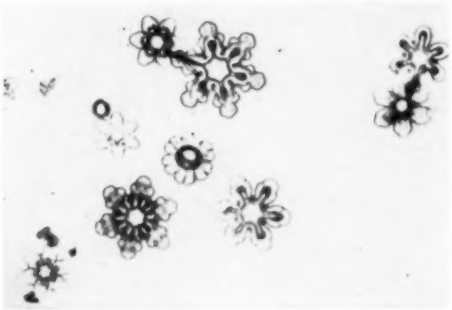
The container should preferably be of glass with a screw type wide-mouthed cover lined with aluminum. The jar should have a capacity of 2–4 oz. with solution depth of 2–2½ inches. Glass microscope slides with 1 × 3″ surface are excellent for collecting the crystals.

Several clean microscope slides may be stored in the cold solution so they are ready to be used as needed.

A half-inch high cardboard tray with its bottom covered with a layer of absorbent paper or blotting paper should be prepared and placed on the floor of the chamber. This is used for holding the sampling slide when replicas are being made. This box and liner should preferably be black so as to blend with the black cloth lining of the chamber.

Making the Replicas

Assuming that the cold chamber is cooled to the range of − 15 to − 20° C. and that a one per cent replica solution containing a clean glass microscope slide is cooled to − 5° C. near the top of the chamber; a supercooled cloud is formed in the chamber, and treated with some appropriate seeding agent such as dry ice, silver iodide, copper sulfide, or other source of effective nuclei for initiating the formation of large numbers of ice crystals. The cold wet slide is swiftly withdrawn from the replica solution, lowered to the bottom of the chamber, and placed so that its flat surface is slightly tilted. This may be accomplished by resting the upper dry edge of the slide on the top edge of the cardboard tray. In this position the replica solution drains toward the bottom of the slide, although all of the surface which had been immersed in the solution remains wet for several minutes. While in this condition ad-

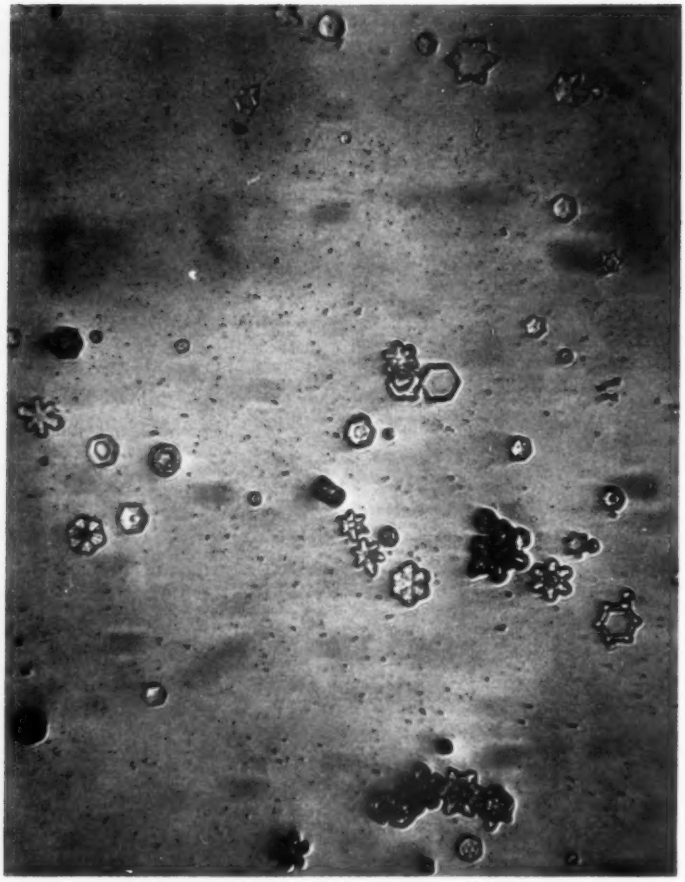


Snow crystal replicas prepared by the author in a cold chamber.

ditional moisture should be continuously supplied to the ice crystal cloud so that the crystals grow rapidly and fall out onto the floor of the chamber. A certain proportion will thus fall on the surface of the wet slide. Care should be exercised that the moist air supplied to the chamber is not directed toward the sampling slide, but rather to the region on the opposite side of the chamber. With properly oriented, indirect illumination, it is possible to watch the crystals fall into the replica solution wetting the slide. After the slide has been exposed to the falling ice crystals for a few minutes, a fairly high concentration of crystals will have landed on the wet film with most of them being covered by the solution either from sinking into it or by the surface creep phenomenon.

The slide may then be placed in a vertical position, the excess ridge of liquid which has drained to its lower edge removed by contact with the absorbent pad on the bottom of the cardboard tray, and the slide then allowed to dry while inclined on a nearly vertical position. Evaporation of the ethylene dichloride solution requires from five to twenty minutes, depending on such things as the size of the chamber, its temperature, ventilation, and the degree of saturation of the air with the evaporating solvent. The best replicas form under conditions in which the solvent evaporates rapidly.

Good replicas require that sufficient solution is present for both surfaces to be coated; the solvent evaporates rapidly and the dry residue remains clear and transparent. If the



A typical area of snow crystal replicas prepared in a cold chamber. Photo by author.

replica solvent shows a tendency for whitening, the replicas are generally poor, since this indicates moisture depositing in the evaporating coating. This tends to happen when the initial solution is too cold, when evaporation proceeds too rapidly, or when the film is contacted by too much liquid moisture.

If good replicas are obtained, they are best studied with a projection microscope on the ground glass screen of a photomicrographic camera or directly under a microscope. A 42 × objective and 4 × ocular provide suitable enlargement for adequate observation or photography.

The Preparation of Replicas of Natural Snow

Samples of snow falling in natural storms may be obtained in the same manner as is used in the cold chamber. If anything, the method is even simpler. Larger sampling surfaces are desirable, ranging from 2 × 3″ microscope slides, 3¼ × 4″ lantern slide plates, sheets of window glass, squares of black surfaced cardboard, sheets of polyethylene or other thin plastic sheets mounted on cardboard, stretched on an embroidery hoop or over the open end of a tin can. A small puddle of 1 or 2 per cent solution cooled to about − 5° C. is poured onto the cold surface, permitted to flow around to form a thin film, and then exposed to the falling snow. Sampling time may vary from a few seconds to several minutes, depending on the intensity of the storm and/or the length of sampling period selected.

After exposure, the sample is put into a well ventilated place, sheltered from falling or blowing snow, having a temperature colder than 0° C. but preferably not colder than − 5° C. The film surrounding the replicas should be transparent when completely dry. Dryness is indicated when the odor of ethylene dichloride has disappeared. Not until this is the case should the replicas be permitted to warm above the melting point of the ice. When melting occurs, the water from the crystal evaporates through the thin surface film which constitutes the upper layer of the "fossil" crystal. This hollow cavity reflects and scatters light in an almost identical manner as that of the original crystals.

Highs and Lows (*Continued from page 131*)

Highs enter the Appalachian region along two principal paths. The most frequent, from the northwest, is essentially a continuation of the zonal track of summer across the northern United States, but displaced slightly to the south. The second path, from the southwest, may be considered as a precursor of the winter track through the southern United States, but shifted a few degrees to the north. Both of these tracks are composed primarily of anticyclones originating in middle latitudes: either in the eastern Pacific, which contributes more highs to the United States in October than in any other month; the Great Basin, which leads the hemisphere in anticyclogenesis during October; or the northern Plains, which has the second largest number of highs per 5° box in the hemisphere. Some highs of polar origin also find their way into the Appalachian region, either directly from central Canada through the Great Lakes, or indirectly from western Canada via the northern Plains.

The principal anticyclone tracks for October differ from those of September primarily in lying further south. This southward displacement is evident in all sectors of the Northern Hemisphere except the Atlantic and east Asia and is most pronounced in the Pacific, western and southern United States, and Europe. Another difference is the fact that secondary anticyclone tracks disappear over bodies of water such as the Bering Sea, Aleutian area, southeast Gulf of Alaska, and Lake Superior. At the same time new centers of maximum anticyclone frequency appear over rapidly cooling land areas such as Algeria and the Great Basin, and anticyclone frequency increases in much of the United States, western Canada, Greenland, and east Asia.

Windstorm Booklet

A 44-page illustrated booklet on Windstorm Damage Prevention has been issued by the National Board of Fire Underwriters, 85 John St., New York 38, N. Y. Copies may be had upon request.

Weatherwatch

A Favorable Crop Season

DAVID M. LUDLUM, *Editor*

Weather conditions across the greater part of the nation underwent a remarkable change from April to May. The lack of persistence from month to month at this time of year is not unusual, as Jerome Namias has pointed out in his extended-range studies. The change in 1956 from April to May, however, was very marked. A low index of westerly circulation had prevailed in April with *below* and *much below* normal temperatures and a rather backward growing season in the great grain belts of the Middle West and the Plains. May produced a high index of westerly flow and unseasonable warmth in all sections except the Northeast and the far Southwest. In portions of the central Great Plains the change was very marked: from as much as six degrees below normal in April to six and more above normal in May.

The upper-air pressure maps amply demonstrate the reasons behind these great temperature reversals. William Klein in the current *Monthly Weather Review* has shown that in April there was an expanded circumpolar vortex with storm tracks well south of normal, the main track in the United States being in the Ohio Valley just to the north of the main jet stream. In May the pressure maps indicated a contracted polar vortex, the jet stream moved northward considerably, and the principal storm track shifted northward from the Ohio Valley to the Upper Lakes-St. Lawrence Valley route.

Polar air which flowed southward without hindrance in April was now confined to the northern border states east of the Upper Lakes. It was one of the coldest Mays on record in northern Maine, and at many stations in the Northeast it was the coldest since 1917. Many late-season marks were set, and the general freeze on 25 May was the latest in modern Weather Bureau records for the area. Later widespread freezes in the Northeast have occurred, those of 11 June 1816 and 5 June 1859 being noteworthy disasters for agricultural interests.

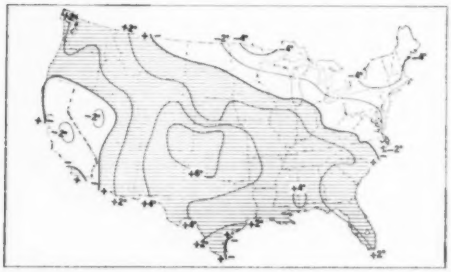
The elongated polar trough over northeastern Canada was the mechanism which provided a path for the Arctic air masses to push southeastward into the New England States and the Maritime Provinces of Canada. A strong northwesterly flow had a long fetch over northwest Canada and the still ice-locked Hudson Bay. A series of polar anticyclones repeatedly followed this path into the Northeast.

One very marked departure from normal in one section of our country usually produces an opposite anomaly in another. Coincident with the northward movement of storm tracks during the month, the sub-tropical high built inland from the Atlantic Ocean and the Gulf of Mexico over Texas and much of the South. The anticyclonic flow around the western border of the high stimulated a southwesterly current from the interior of Mexico and our Southwest into the southern Plains and beyond. A number of points in Texas, Oklahoma, and Kansas reported the warmest month of May on record with persistent 90° plus readings. For Colorado, as a whole, it was the second warmest May on record.

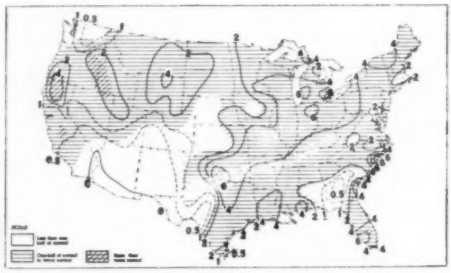
The belt of above normal temperatures extended northwestward from the Gulf of Mexico to the Pacific Northwest. There ridge conditions combined with stronger than normal westerly flow brought milder maritime air from the Pacific, and the general anticyclonic curvature of the flow pattern produced clear skies to permit intense daytime insolation. The far Southwest averaged a bit below normal as showery conditions in the first two weeks of May created above normal cloudiness and lower daytime temperatures.

The precipitation pattern was rather mixed. In general, there were only two areas of heavy precipitation. The California-Nevada area had frequent rains during 1–15 May as a series of small fronts moved inland from a minor trough. Another area of heavy rainfall centered in northern Ohio and the Lower Lakes along the general mixing zone between

MONTH OF MAY 1956



Departure of Mean Temperature from Normal in degrees F. USWB chart.



Total Precipitation in inches. USWB chart.

tropical air flowing up from the Southwest and the persistent polar stream from central Canada. Much convective activity was noted, and the major tornado activity of a rather quiet spring in the severe local storm field took place there. On the 12th and 13th tornadoes and hail storms caused over $10 million damage in southern Michigan. On the 12th at least 20 funnels were reported there; Flint, Michigan, a victim of a major tornado in 1953, again was struck by a whirl which did $4 million damage.

NORTHEAST COLD—The core of the cold air mass in April was located over the northern Plains where places in North Dakota had monthly averages eight degrees below normal. During the late April and early May the zone of intense cold shifted eastward, and by the end of May the greatest departures were confined to the New England States and New York. With the storm track just to the north of the region, a succession of southeastward-moving highs penetrated the Northeast in the wake of each cyclonic disturbance. This series reached a climax on 23–25 May as a deep upper-air polar vortex developed over Labrador and northern Quebec. The main front of the fresh polar air mass cleared the New England coast about noon on the 23rd; at the same time a high crossed the Manitoba-Minnesota border and then moved southeastward to a position where it encouraged the flow of frigid air from icy Hudson Bay into the heart of New England.

After a night of rapid radiation in the polar air, temperatures dropped below freezing on the mornings of the 24th and 25th at many inland points from Maine to West Virginia. At Cavendish, Vermont, the low mark of 19° was reached. At Phillipsburg, Pennsylvania, high in an Appalachian valley, the figure was 22°. A severe frost occurred. Preliminary estimates of crop damage ran to $10 million with Massachusetts truck gardens taking half the loss. Fruits were also hard hit and orchardists seemingly resigned themselves to an unproductive year.

JUNE CIRCULATION—There were important differences in the air flow pattern over the United States during the two months under study, and the shift of the upper-air currents came on the last two days of May. A high index type of westerly flow had featured May with a strong polar low and strong anticyclones in the middle latitudes around the globe. In central and southern United States the anticyclonic regime was particularly well marked, accounting for the persistence of warm May weather in the great interior of the continent.

The principal development from May to June was the rather rapid build-up of a vast continental ridge from northern Mexico northward into central Canada on the last days of May. For many days in early June a second cell of the sub-tropical high appeared over the New Mexico area with a ridge extending to the sub-Arctic. In the Hudson Bay area of Canada a marked minus departure from normal pressure figures had been the chief feature of the May upper-air charts, while the June mean maps showed a very marked plus departure in the same area. Thus a blocking action was created in northern Canada, causing most of the migratory lows to pass south of their usual early summer track: either across the upper St. Lawrence Valley or even further south across northern New England, an unusual circumstance for late June.

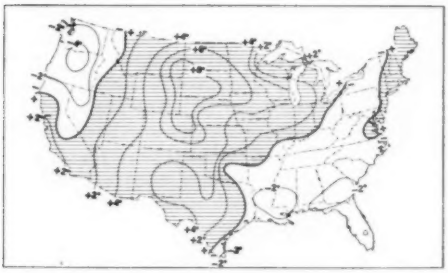
The second major change in June was noted in the area just west of the Pacific Coast. The ridge of May faded away and was replaced by a trough. The center of cyclonic activity was in the Gulf of Alaska, but the trough trailed southeastward to the northern California coast. Thus, cool Pacific maritime air was brought into the Northwest under a cyclonic curvature of the isobars. As a result, it was decidedly cool after the first week of June in the Northwest and rather heavy rainfall for a summer month fell in Oregon, Washington, and Idaho. The late rains kept river levels high which were already swollen from the rapid snow melt in May.

The extensive ridge northward from Texas into the Canadian Arctic permitted tropical air from the deserts of the Southwest to travel northward, and the clear skies under the anticyclonic dome gave intense radiation to maintain the high temperatures of the air masses. International Falls, Minnesota, registered 98°, the absolute maximum in the 14-year span of its records.

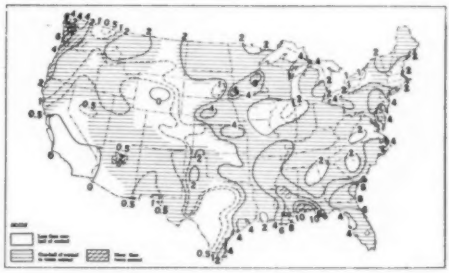
Precipitation was light in this northward moving current of continental origin, especially in Wyoming and Montana and the extreme western part of the northern Plains. The main drought complaints of farmers emanated from this area of dry farming. Further east there were some very heavy rainfalls. The intrusion of a tropical low in mid-June brought copious rains to the entire lower Mississippi basin, and the accompanying cloudy skies lowered daytime temperatures to give the area a minus temperature departure for the full month.

The Northeastern sections of the country, where it had been so cold in May, had varied conditions with frequent changes in air mass from warm tropi-

MONTH OF JUNE 1956



Departure of Mean Temperature from Normal in degrees F. USWB chart.



Total Precipitation in inches. USWB chart.

cal to cool polar as trailing fronts from cyclones moving across Canada provided frequent wind shifts. Although temperature soared to 95° and higher on 13–16 June in most Eastern States (La Guardia Field, New York City 99°), the mercury also dropped to almost record lows on the 18–19th. The month averaged out near to normal over all of the Northeast, after three months of consistently below normal readings and a very backward spring.

A WELCOME TROPICAL STORM—The first tropical storm of note moved inland over Louisiana near Isle Derniere and passed to the west of New Orleans on the morning of 13 June. It first appeared on regular weather maps in the Yucatan peninsula area on the 11th and followed a track almost directly north. Although not deemed to be of sufficient force to be given an "Anna" designation, it was an important event for agricultural interests. The pressure read about 1004 mb (29.60") as it crossed the coast and winds were in the 60 mph class. Local wind and light flooding damage occurred in the eastern quadrant of the storm as it moved inland, and five people were reported lost in Mississippi and adjacent waters as a result of the blow.

By far the most important effect of the storm was the copious rains which fell over an area which had been getting close to a drought situation at a very critical time of the growing season. The following totals were reported from first-order stations: Louisiana, Burrwood 9.01" and New Orleans 8.85"; Mississippi, Vicksburg 7.70"; Arkansas, Arkadelphia 3.35". The canopy of rain and cloud extended eastward to central Georgia, northward to Kentucky, and westward over all of Arkansas. Though farm work was interrupted, the rains brought great ultimate benefits to all crops and now excellent yields were in prospect.

The center of the sub-tropical low had a closed circulation aloft which accounts for its ability to move such great quantities of moisture from the Gulf of Mexico and dump them on the cotton and corn fields of the Deep South. The storm center curved cyclonically northwestward after crossing the coast and passed near Little Rock with only moderate winds late of the 14th. Next day it had merged with a developing trough just east of the Rocky Mountains. Cloudy skies and showers persisted over the lower South for several days thereafter.

THE CROP SITUATION—The agricultural outlook as June drew to a close was mainly on the favorable side. The farm situation, of course, is always a varied one from section to section and from crop to crop, but the outlook for excellent crops in all areas was brighter in 1956 than it had been since the droughty period started in 1952. The moisture supply was generally adequate from the Mississippi Valley eastward with the exception of the immediate coastal South Atlantic States. In Iowa the early spring drought had been mainly checked, and in western Texas and Oklahoma June rains gave promise of good harvests. The chief drought complaints came from the northwestern Plains in the Dakotas and Montana, and in the New Mexico and southwestern Texas area, seemingly perennial drought sufferers.

The chief crops complaint centered around oats in the western Plains. Wheat, both winter and spring varieties, were in good shape generally, and prospects of lowering our traditional surplus in this grain appeared rather dim. Corn made a slow start in the East, but warm June weather brought rapid growth. In the Middle West corn made excellent progress in June and a normal crop appeared in prospect.

In the South the cotton picture was bright after the rains of the mid-June storm period as hot, dry weather succeeded and favored rapid growth, cultivation, and weevil control. From Texas reports were spotty. On irrigated lands cotton growth was good, but lack of moisture in southern non-irrigated counties was retarding the crop. Reports from cotton area of Arizona and California were very favorable, as were prospects for the fruit crop in the far Southwest.

(Continued from page 110)

Additional hurricane research meteorologists have been assigned to the hurricane forecast centers at New Orleans, Miami, and Washington to assist in tracking future path, speed, and intensity of hurricanes.

The new term "hurricane watch" will be employed. This replaces the term "hurricane alert" which gave rise to past confusion.

All hurricane advisories will be issued at the newly-established National Hurricane Information Center at Miami concurrent with the release of identical bulletins at all field offices.

A new storm surge forecast program will be instituted to warn of high water along coastal areas.

An improved flood warning service with headquarters at Windsor Locks, Connecticut, has been provided for New England.

Additional emergency communications facilities have been set up to speed exchange of data and the issuance of warnings.

A public information program has been started. Leaflets describing the warning service and advising as to precautions to take to preserve life and prevent loss of property will be widely distributed. A new movie on the Hurricane Warning Service will be shown over TV and made available to civic groups for local showings.

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The Hurricane Hunters. Ivan Ray Tannehill. Dodd, Mead and Co., New York, 1955. 271 p., illustrated. $3.00.

The Hurricane Hunters, a fast-moving, informal account of the men who seek and track tropical storms from the air, as well as from the land and sea, is the latest addition to the growing list of books by Ivan Ray Tannehill, familiar to many weather enthusiasts as the author of *Weather Around the World* and *Drought; Its Causes and Effects.*

Here is a collection of anecdotes, held together by the power of the antagonist in its conflict with man. Told with restraint and in simple language, the narrative, however, occasionally suffers from apparently hurried writing.

The historical background to today's airborne hurricane hunters is developed in the first third of the book with the remainder being devoted mainly to descriptions of U. S. Navy and Air Force reconnaissance flights into particular storms of recent years, including Carol and Hazel of 1954. The author has capitalized on the value of spontaneity in these later chapters by letting the pilots and observers recount, in their own words, adventures so few of us will ever experience. Coupled with the author's insistence upon underwriting the more dramatic aspects, these passages create an appropriately taut atmosphere that "makes" the book.

An index and set of references are unfortunately lacking and would be of help to the reader; presumably he should turn to the author's *Hurricanes; Their Nature and History* for a bibliography. While the two books overlap to a considerable extent, they have been approached from two different points of view, with the result that they supplement rather than compete against each other.

Appearing at a time when public interest continues at the high level generated by the 1954 and 1955 hurricane seasons (a fact undoubtedly enjoyed by both author and publisher), *The Hurricane Hunters* should fall into the hands of many a general reader, who, if he is at all interested in the natural world about him, will promptly enjoy a few hours of pleasant and informative reading.

JAMES M. HAVENS

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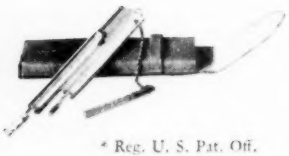

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